Alberta

ALBERTA OFFICE OF COAL RESEARCH & TECHNOLOGY

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Cover Photo: A slurry of agglomerated coal moves through a laboratory-scale pipeline at Alberta Research Council

An Economic Analysis of Coal Pipeline Systems

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of our resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal and conventional energy resources, as well as energy conservation and renewable energy. Program administration is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In recognition of the importance of coal to Alberta's economy, the Alberta Office of Coal Research and Technology was established in 1984 within Alberta Energy and Natural Resources (now Alberta Energy). Its primary purpose is to encourage the development and application of new technologies related to Alberta coals. The Office provides funding contributions to research and development projects in industry, academic institutions and other research establishments and monitors their progress in an overall program of improving the production, transportation and marketability of Alberta coals.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page six.

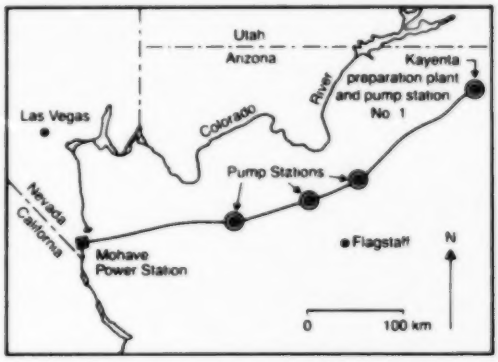
An Economic Analysis of Coal Pipeline Systems

During the past two decades, demand for Alberta thermal coals has increased in both domestic and overseas markets. In Alberta, new electricity generating stations were built which consume subbituminous coals that are mined nearby. At the same time, sales of bituminous thermal coals increased in such markets as European and Pacific Rim countries and in central Canada.

To transport coal to Ontario or to west coast ports for shipment overseas, railway companies began using unit trains capable of hauling 10,000 tonnes of coal at a time. Because rail haul distances are long, transportation costs add up to be a significant portion of the overall costs of Alberta coals. For example, rail haul accounts for 35 per cent of all the costs to mine, clean and deliver Alberta coals to Pacific ports. Nevertheless, those total costs were still low enough to be competitive in world markets during the 1970s although the market situation during the 1980s, and projections for the next decade, suggest that further cost reductions and improvements in efficiency will be needed if Alberta coals are to remain cost-competitive. Therefore, each element in the mine-to-customers chain is being examined for opportunities to cut costs. This has included investigations of some transportation alternatives including proposals to use pipelines to move slurries of Alberta coal over short and long distances.

The technical feasibility of moving coal slurries to the west coast by pipeline was demonstrated in a 1980 study. It prompted a subsequent examination in 1984 of the economics of transporting a variety of slurry configurations by pipeline. This study, which was co-funded by the Alberta Office of Coal Research and Technology and Pembina Resources Limited, was performed by several research groups under the direction of Pembina Resources. Results of the investigation were published in 1985 in a two-volume report entitled "Slurry Pipeline System Investigation of Western Canadian Coals".

A typical unit train enroute to west coast terminals
(Photo courtesy of Canadian National Railways)



The Black Mesa Pipeline, which extends 439 km across Arizona, and has been operating since 1970, conveys slurried coal from a mine to a power plant

Study Approach

While estimates of coal behaviour in a pipeline can be made from generalized correlations that consider the physical properties of coal, the investigators regarded this as an unsatisfactory approach when several types of coal slurry systems are to be compared with each other. It was thought a more useful comparison could be made if experimental results for the different pipelining methods were available. Furthermore, each coal slurry involves different coal preparation techniques which can alter the way coal is handled at the tidewater end of the pipeline. Therefore, it was felt that a comprehensive economic analysis must consider not only the pipeline portion of the delivery system, but it must also weigh the influence on costs of coal cleaning and slurry preparation as well as any costs associated with recovery and storage of coal at the delivery terminal. Also, any economic consideration of coal delivery options should make allowance for the need to transport coal over short or long distances.

Having established these criteria as the basic requirements of the study, the investigators went on to examine three types of thermal coals, in five coal slurry systems, over three transportation distances.

The three Alberta coals used in the experimental test programs were:

- raw and washed high volatile bituminous coals from the Foothills region
- raw subbituminous coal from the Plains region

They were transported in five slurry systems, namely:

- slurries having a fine particle size distribution
- slurries with an intermediate particle size distribution
- coarse particle size distribution slurries
- dense phase coal-water mixtures
- agglomerated coal slurries

The hydraulic behaviour of agglomerated coals was investigated using a pilot-scale pipeline loop at Alberta Research Council

The three transportation distances were classified as:

- long (1000 km), representing transportation to the west coast or to Ontario
- intermediate (300 km), representing transportation for fuel uses within Alberta
- short (25 km), representing local transportation from a mine to a cleaning plant or railway

To provide a basis for detailed technical and economic comparisons of the various alternatives, hydraulic studies were carried out using laboratory-scale pipelines at three research facilities. Pipeline loop tests using 50 mm diameter pipe were performed at the research laboratory of Pembina Resources. Here, fine and intermediate particle size distribution slurries were studied. At the Saskatchewan Research Council, the hydraulic characteristics of coarse coal slurries were measured in loops of 158 mm diameter pipe while, at the Alberta Research Council, agglomerated coals were studied as they moved through loops of 50 mm diameter pipe. The hydraulic behaviour of coal-water mixtures was estimated after consultation with researchers who are actively working with them.

After hydraulic characteristics were measured under laboratory conditions, mathematical models were used to predict the behaviour of each type of slurry in commercial-scale pipelines capable of carrying two million or more tonnes of coal per year. Two mathematical models were used. They were the Pseudofluid Method and the Parameter Matching Method.

Coarse coal slurries were studied in this pipeline at Saskatchewan Research Council

Results

Hydraulic Characteristics

In the case of fine particle size distribution slurries, the results of hydraulic testing were found to be consistent with previous measurements and behaviour of fine particle slurries. This was taken to mean that projections concerning hydraulic behaviour in commercial-scale pipelines should be reliable even with the large degree of scale-up that would be required for pipelines capable of carrying up to 10 million tonnes of coal per year.

On the other hand, intermediate particle size distribution slurries have not been studied extensively in the past. With a rather limited background of data to use as a reference point and because of complications created by a significant load of suspended solids, researchers working on this type of slurry found that the projected hydraulic behaviour in scaled-up systems was less reliable than for fine particle size distribution slurries. In turn, this greater amount of uncertainty is reflected in a lower degree of confidence in the economic estimates that were made.

Because coarse coal slurries were studied in a pipeline that was relatively large in comparison with those used for other slurries, the investigators believe the projected hydraulic behaviour of coarse coal slurries in commercial-scale pipelines can be used with a high degree of confidence.

In the case of agglomerated coals, there is little information on their hydraulic characteristics and no satisfactory model of flow behaviour is available. Consequently, economic analyses suffer from a lower degree of confidence caused by a lack of important information, such as the relationship between particle size and pipe diameter.

Economic Analysis

In terms of energy delivery, the most promising pipeline option for moving two million tonnes of coal per year over a distance of 1000 kilometres is to transport washed bituminous coal in the form of a fine particle size distribution slurry. It was also found that costs are sensitive to economies of scale. When throughput is increased from two million to 10 million tonnes per year, pipeline operating costs are predicted to drop by 50 per cent while the costs to operate the coal/slurry preparation plant and the dewatering and drying facility decrease by 35 per cent.

Intermediate particle size distribution slurries showed higher operating costs because of higher pressure gradients in the pipeline but the investigators believe the economic projections for this configuration and for agglomerated coals are incomplete because of the low level of confidence in scale-up calculations.

The costs to deliver dense coal-water mixtures by pipeline are higher because of the high costs to grind coal and to add chemicals to the formulation. This also results in a higher mining cost because more extensive beneficiation results in lower coal yields.

On the basis of two million tonnes of coal per year, in the form of a fine particle size distribution slurry, having been found to be the best option for delivery over long distances, this mode of transportation was examined for intermediate distances to allow comparisons between washed and unwashed coal. The least expensive option was found to be delivery of raw subbituminous coal although washed subbituminous is only about 25 per cent more expensive on the basis of delivered energy. It costs an additional 25 per cent to transport raw bituminous coal.

The most likely applications for delivery over short distances would be, for example, transportation within a plant site or from a mine to a wash plant. Under these conditions, economic analyses showed that the costs to transport coarse coal slurries of raw bituminous coal were representative of the other coals that were studied.

Of particular interest to the coal industry, Pembina's researchers found that, on a per tonne-kilometre basis, the projected operating costs for slurry pipelines that could carry coal 1000 km, ranged from $0.012 to $0.015 for fine coal slurries and intermediate coal slurries without drying, or from $0.021 to $0.023, with drying. On an equal delivery basis, this amounts to about $23 per tonne which, when mining costs of up to $25 per tonne are added, is competitive with present costs of approximately $45 to mine coal and deliver it by rail to west coast ports. Costs for other slurry systems and for other transportation distances are shown in the accompanying table.

The Alberta Office of Coal Research and Technology believes it is appropriate to consider the possibility that existing oil pipelines might be used to transport coal slurries during times when spare capacity exists. This would avoid the need to build new pipelines specifically for coal slurries. Already this approach has been used to send batches of methanol from Alberta to Vancouver by way of the Trans Mountain Pipeline. The concept of batch delivery of coal is now being considered.

Estimated Direct Costs for Slurry Pipelining ($/tonne-km)

	5 km	25 km	300 km	1000 km	
				Without drying	With drying
Fine Coal Slurry	-	-	$0.01 - $0.03	$0.012 - $0.015	$0.021 - $0.023
Intermediate Coal Slurry	-	-	-	$0.012 - $0.015	$0.021 - $0.023
Coarse Coal Slurry	$0.19	$0.08	-	-	-
Dense Phase Coal Water Mixture	-	-	-	$0.035	-
Agglomerated Coal Slurry	-	-	-	$0.056	-

(Source: *Slurry Pipeline System Investigation of Western Canadian Coals*, Pembina Resources Limited)

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